CASS Technical Report

Environmental Modelling to Support NPDES Permitting for Velella Epsilon Offshore Demonstration Project in the Southeastern Gulf of Mexico

Lead Scientists: Kenneth Riley, Ph.D. and James Morris, Ph.D.
Environmental Engineer: Barry King, PE
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This analysis uses an environmental model to simulate effluent to inform the NMFS Exempted Fishing Permit (EFP) and EPA National Pollutant Discharge Elimination System (NPDES) Permit for the Velella Epsilon Offshore Demonstration Project. Kampachi Farms, LLC (applicant) proposes to develop a temporary, small-scale demonstration net pen operation to produce two cohorts of Almaco Jack (*Seriola rivoliana*) at a fixed mooring located on the West Florida Shelf, approximately 45 miles offshore of Sarasota, Florida (Figure 1; Table 1). Scientists from the NOAA Coastal Aquaculture Siting and Sustainability (CASS) program worked with the EPA project manager and the applicant to develop estimates of effluents and sediment related impacts for the offshore demonstration fish farm.

A numerical production model for two cohorts of Almaco Jack was constructed based upon anticipated farming parameters including configuration (net pen volume and mooring configuration), fish production (species, biomass, size) and feed input (feed rate, formulation, protein content). Using industry standard equations, daily estimates of biomass, feed rates, total ammonia nitrogen production, and solids production (*see Microsoft Excel Spreadsheet – Velella Epsilon Production Model*) were developed under a production scenario to estimate the maximum biomass of 20,000 fish that would be grown to 1.8 kg in approximately 280 days. The total biomass produced with one cohort and no mortality was determined to be 36,280 kg. The density in the cage at harvest would be 28 kg/m^3. Fish will be fed a commercially available growout diet with 43% protein content. Daily feed rations range from 12 kg at stocking to a maximum total daily feed ration equivalent to 399 kg at harvest. Maximum daily excretion of total ammonia nitrogen is estimated at 16 kg and solids production is 140 kg. A total of 66,449

The **Coastal Aquaculture Siting and Sustainability (CASS)** program supports works to provide science-based decision support tools to local, state, and federal coastal managers supporting sustainable aquaculture development. The CASS program is located with the Marine Spatial Ecology Division of the National Centers for Coastal Ocean Science, National Ocean Service, NOAA. To learn more about CASS and how we are growing sustainable marine aquaculture practices at: https://coastalscience.noaa.gov/research/marine-spatial-ecology/aquaculture/ or contact Dr. Ken Riley at Ken.Riley@noaa.gov.

kg of feed will be used for production of each cohort of fish to achieve a feed conversion ratio (FCR) of 1.8. Summary statistics were developed for each cohort and the entire project (Table 2).

Table 1. Boundary locations for the Velella Epsilon Offshore Aquaculture Project.

Location	Latitude	Longitude
Northwest corner	27.072360 N	-83.234709 W
Northeast corner	27.072360 N	-83.216743 W
Southwest corner	27.056275 N	-83.216743 W
Southeast corner	27.056275 N	-83.234709 W

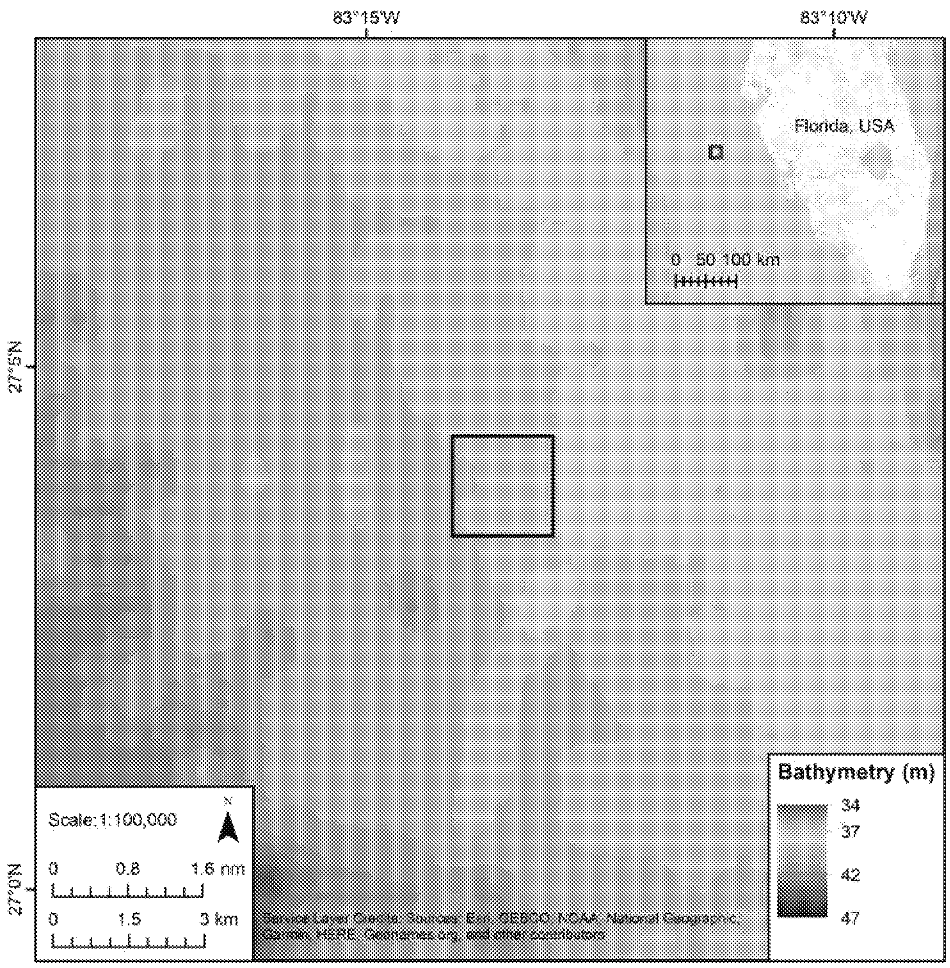

Figure 1. Bathymetric map of proposed Velella Epsilon Offshore Aquaculture Project.

Table 2. Summary statistics for the Velella Epsilon Offshore Aquaculture Project.

Farming parameter	Value
Growout duration	280 days per cohort
Total number	20,000 fish per cohort
Individual size at harvest	1.8 kg
Maximum biomass	36,280 kg
Cage density at harvest	28 kg/m^3
Maximum daily feed rate	399 kg
Total feed used	66,449 kg
Feed conversion ratio	1.8

In order to estimate sediment related impacts, a depositional model (DEPOMOD; Cromey et al 2002) was parameterized with data from the production model and environmental and oceanographic data on the proposed offshore location. DEPOMOD is the most established and widely used depositional model for estimating sediment related impact from net pen operations. DEPOMOD is a particle tracking model for predicting the flux of particulate waste material (with resuspension) and associated benthic impact of fish farms. The model has been proven in a wide range of environments and is considered through extensive peer-review to be robust and credible (Keeley et al 2013). Although this modelling platform was initially developed for salmon farming in cool-temperate waters (Scotland and Canada), it has since been applied and validated with warm-temperate and tropical net pen production systems (Magill et al. 2006; Chamberlain and Stucchi 2007; Cromey et al. 2009; Cromey et al. 2012). Coastal managers responsible for permitting aquaculture worldwide have been using this modelling platform because it produces consistent results that are field validated and comparable (Chamberlain and Stucchi 2007; Keeley et al 2013). It is routinely used in Scotland and Canada to set biomass (and thereby feed use) limits and discharge thresholds of in-feed chemotherapeutants (SEPA 2005). Further, the model output has been used to develop comprehensive and meaningful monitoring programs that ensure environmentally sustainable limits are not exceeded (ASC 2012).

Traditionally a baseline environmental survey is used to inform water quality and depositional models with site specific analysis of currents, tidal flows, sediment profiles, and benthic infaunal profiles (species richness and abundance). In the absence of a survey, data were collected from oceanographic and environmental observing systems in the vicinity of the project area. Current data were obtained from NOAA Buoy Station 42022 along the 50-m isobath and located 45 miles northwest of the project location (27.505 N, 83.741 W). Currents were recorded continuously from July 2015 through April 2018. Currents were measured at 1-meter intervals from 4.0 meters to 42.0 meters below the surface (Table 3). Bathymetric data were obtained from the

NOAA Coastal Relief Model. Bathymetry was resampled to 10 x 10 meter grid cells using a bilinear interpolation to all for use within the deposition model.

Table 3. Water column related impacts for the Velella Epsilon Offshore Aquaculture Project. Values represent summation of daily values over a 280-day production cycle.

Parameter	Value (kg)
Total solids production	23,257
Total ammonia nitrogen	2,743
Total oxygen consumption	16,612
Total carbon dioxide production	19,187

The depositional model was executed for two different production simulations that assume maximum standing biomass and maximum feed rate, which is characteristic when the fish are at pre-harvest size. The first simulation represented the maximum standing biomass for the Velella Epsilon Offshore Aquaculture Project. The model was run for 365 days assuming a net pen with a constant daily standing biomass at 36,275 kg (28 kg/m^3) and a daily feed rate of 1.1 percent of biomass or equivalent to 399 kg of feed. The second simulation doubled production to assess sediment related impacts at higher levels of biomass and feed rates. The second simulation at a higher level of production was intended to aid EPA in development of an environmental monitoring program. Under the second simulation, the model was run for 365 days assuming two net pens each with a combined constant daily standing biomass at 72,550 kg (28 kg/m3 per net pen) and a daily feed rate of 1.1 percent of biomass or equivalent to 798 kg of feed.

Waste feed and fish fecal settling rates are important determinants of distance that these particles will travel in the current flow. The model does not allow the settling velocity of particles to change through the growing cycle. The values used for feed and feces represented those that would be encountered during the period of highest standing biomass, largest feed pellet size, and highest waste output. Each simulation assumed maximum standing biomass each day of the simulation with a fecal settling velocity at 3.2 cm/s. Many marine fish have fecal settling velocities ranging from 0.5 to 2.0 cm/s, while salmonids tend to have higher settling velocities ranging from 2.5 to 4.5 cm/s. Fecal settling velocities applicable to salmon production were used because they are well studied, validated, and allow for maximum benthic impact assessment. Standard feed waste was estimated at 3% and the food settling velocity was 9.5 cm/s. Pelleted fish feed is the single largest cost of fish farming, and because of this expense, farms use best feeding practices to ensure minimal loss. Feed digestibility and water content were set at 85% and 9%, respectively, which are standards based on technical data provided by feed manufacturers. All other model parameters were consistent with existing net pen farm waste modelling methodologies (Cromey et al. 2002a,b) and regulatory farm modelling standards (SEPA 2005).

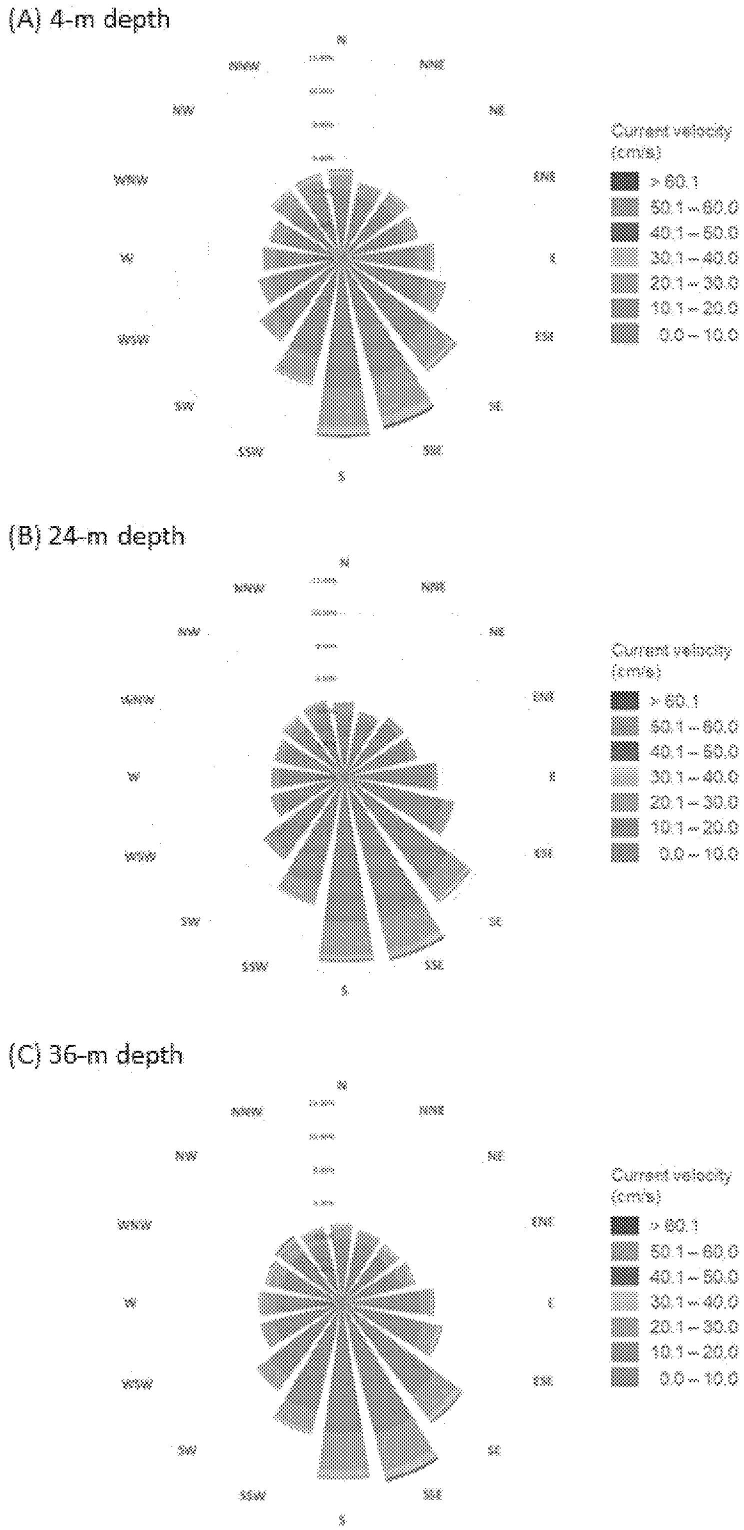

Figure 2. Distribution of current velocities (cm/s) and direction for NOAA Buoy Station 42022 located along the 50-m isobath approximately 45 miles northwest of project location. Currents are reported for water column depths of 4 m, 24 m, and 36 m.

Table 4. Current velocities (cm/s) for NOAA Buoy Station 42022 located along the 50-m isobath approximately 45 miles northwest of project location. Average current velocities are reported with standard deviation.

Depth (m)	Average current (cm/s)	Maximum current (cm/s)
4	14.6 ± 8.1	83.9
10	12.8 ± 8.0	80.3
20	12.2 ± 7.3	67.6
30	13.8 ± 8.2	70.8
40	12.9 ± 7.6	68.7

Table 5. Model settings applied for depositional simulations of an offshore fish farm in the Gulf of Mexico.

Input variable	Setting
Feed wastage	3%
Water content of feed pellet	9%
Digestibility	85%
Settling velocity of feed pellet	0.095 m/s
Settling velocity of fecal pellet	0.032 m/s

Offshore fish farms can be managed in terms of maximum allowable impacts to water quality and sediment that are based on quantifiable indicators. This project will be difficult to monitor and detect environmental change because of the relatively low level of production associated with a demonstration farm and the nature of the net pen configuration deployed and moving about on a single point mooring.

Overall, this analysis found that the proposed demonstration fish farm is not likely to cause significant adverse impacts on water quality, sediment, or the benthic infaunal community. Water quality modelling demonstrated that at the maximum farm production capacity of 36,280 kg only insignificant effects would occur in the water column. We believe that the excreted ammonia levels of 16 kg per day will be rapidly diluted to immeasurable values near (within 30 meters) of the net pen under typical flow regimes of 12.8 ± 8.0 cm s^{-1}. Dilution models could be used to estimate nearfield and farfield dilution as used in conventional ocean outfall systems.

However, based on our experience with offshore aquaculture installations and development of modeling and monitoring programs, we believe that ammonia levels will be difficult to detect beyond the zone of initial dilution.

The model does not allow the net pen or mooring configuration to move in space or time, therefore, the model was executed at a fixed location (27.064318, -83.225726) in the center of the project location (i.e., farm footprint). Net depositional flux was predicted in g m^{-2} yr^{-1} on a two-dimensional grid overlaid on the farm footprint. The grid size was selected such that it would encompass the whole depositional footprint. The distribution of deposited materials beneath the cage is a function of local bathymetry and hydrographic regime. In low current speed environments, only limited distribution of the solids footprint occurs. As current speeds increase, greater dispersion of solids occurs during settling resulting in a more distributed footprint. Greater water depth at a site results in increased settling times and result in a more distributed footprint. Solids distribution is even greater where bottom current speeds are high causing sediment erosion and particle resuspension and redistribution.

The predicted carbon deposition and magnitude of biodeposition for the single and dual cage scenarios were estimated over a 2.04 km by 2.04 km evaluation grid. The grid is partitioned into cells numbering 82 east-west by 82 north-south and identified as 1-82 in both directions. The units of the axes in both Figures 3 and 4 are these cell counts. The dimension of a single cell therefore is 2,040m/82=24.87 m. The depositional model predicted and integrated at each one-hour step, the total carbon that ended up in each cell in the model grid, of which there are 82 x 82 = 6,724 cells. At the end of an execution run the accumulated mass of carbon within each cell is reported. Predicted annual benthic carbon deposition are presented in Figures 3 and 4. Frequency histograms of the carbon deposition per cell were created to help with interpretation of results. The depositional data derived from the frequency histograms are presented in Table 6 and 7.

Table 6 shows the distribution of carbon that results from a single net pen operated for one year at maximum standing biomass. Of the 6,724 computational cells, 1,386 had no carbon from the farm. Over 88% of the cells received less than or equal to 1 gram of carbon. Only 2 cells on the farm measured more than 4 grams of carbon over the year-long simulation.

Table 7 shows the distribution of carbon that results from a two net pens operated for one year at maximum standing biomass. Similar to the depositional model with one cage, over 75% of the cells received less than or equal to 1 gram of carbon. One cell was calculated to receive more than 11 grams, but it is a minuscule mass of carbon to be assimilated by a square meter of ocean bottom.

Table 6. Frequency of carbon deposition within 6,724 cells, each measuring 619 m^2, over a 4.16-km^2 grid system. Values represent an annual sum of carbon deposition resulting from an offshore fish farm with a constant standing stock biomass of 36,275 kg.

Carbon deposition ($g/m^2/yr$)	Occurrence (N)	Frequency (%)
0	1,386	20.6
0.1 – 1.0	4,561	67.8
1.1 – 2.0	620	9.2
2.1 – 3.0	141	2.1
3.1 – 4.0	14	0.2
4.1 – 5.0	2	0.03

Table 7. Frequency of carbon deposition within 6,724 cells, each measuring 619 m^2, over a 4.16-km^2 grid system. Values represent an annual sum of carbon deposition resulting from an offshore fish farm with a constant standing stock biomass of 72,550 kg.

Carbon deposition ($g/m^2/yr$)	Occurrence (N)	Frequency (%)
0	999	14.9
0.1 – 1.0	4,086	60.8
1.1 – 2.0	903	13.4
2.1 – 3.0	390	5.8
3.1 – 4.0	200	3.0
4.1 – 5.0	75	1.1
5.1 – 6.0	40	0.6
6.1 – 7.0	20	0.3
7.1 – 7.0	7	0.1
8.1 – 9.0	3	0.04
9.1 – 10.0	0	0.0
10.1 – 11.0	0	0.0
11.1 – 12.0	1	0.01

Because of physical oceanographic nature of the site including depth and currents (>10 cm/sec), dissolved wastes will be widely dispersed and assimilated by the planktonic community (Rensel et al. 2017). The results of the depositional model show that benthic impacts and accumulation of particulate wastes would not be detectable or distinguishable from background levels through measurement of organic carbon, even when the standing stock biomass is doubled. The final component or step in the modeling process is to predict some measure of change in the benthic community as a result of increased accumulation of waste material. Deposition of nutrients may result a minor increase in infaunal invertebrate population or no measureable effect whatsoever.

As part of the model assessment, benthic community impact was predicted by an empirical relationship between depositional flux (deposition and resuspension) and the Infaunal Trophic Index (ITI). The ITI is a biotic index that has been used to quantitatively model changes in the feeding mode of benthic communities and community response to organic pollution gradients (Word 1978, 1980; Maurer et al. 1999). ITI scores are calculated based on predicted solids accumulation on the seabed (g m^{-2} yr^{-1}). ITI scores range from 0 to 100 g m^{-2} yr^{-1} and are banded in terms of impact as:

- 60 < ITI < 100 – benthic community normal
- 30 < ITI < 60 – benthic community changed
- ITI < 30 – benthic community degraded.

Correlations between predicted solids accumulation and observed ITI and total infaunal abundance have been established using data from numerous farm sites around the world. Among the findings of these studies, a completely unperturbed benthic community at equilibrium is considered to have an ITI of 60 and an ITI rating of 30 is the boundary where the redox potential of the upper sediment goes from positive to negative and sulfide production begins. A standard approach in Europe and Canada is to use an ITI of 30 as a lower limit for acceptable impacts. In the present study with the Velella Project, the two model simulations resulted in ITI predictions ranging from 58.67 to 58.81. The predicted ITI close to 60 suggests that the Velella Project, as proposed, will not likely have a discernable impact on the sediment or benthic infaunal community around the site.

In summary, the resulting model predictions covered a range of outputs representing both submitted farming parameters and a worst-case scenario (doubled standing stock biomass) for the Velella Epsilon Project. We conclude that there are minimal to no risks to water column or benthic ecology functions in the subject area from the operation of the net pen as described in Kampachi Farms, LLC applications for EFP and NPDES permits.

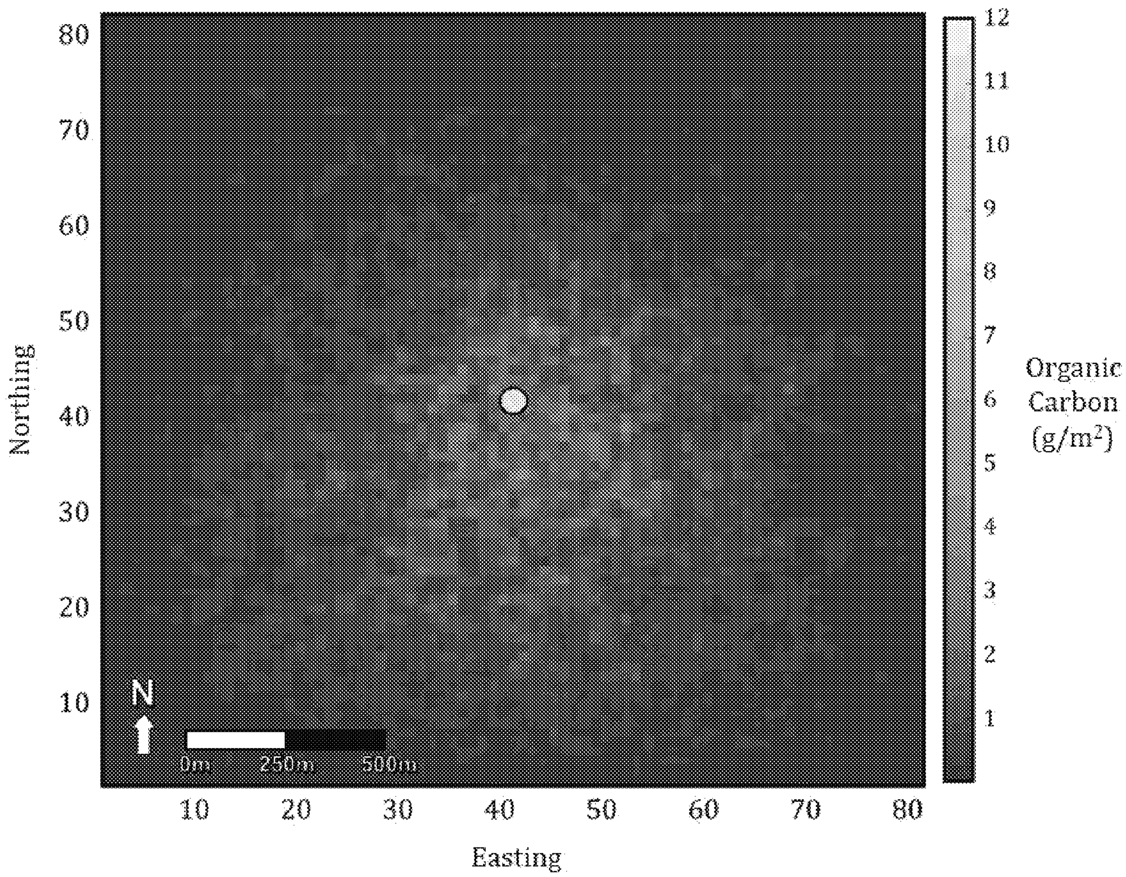

Figure 3. Predicted annual benthic carbon deposition field beneath one net pen with a standing stock biomass of 36,280 kg of Almaco Jack (*Seriola rivoliana*). Gray circle indicates center position of the net pen. Axes indicate simulation cell numbers and deposition mass is in grams.

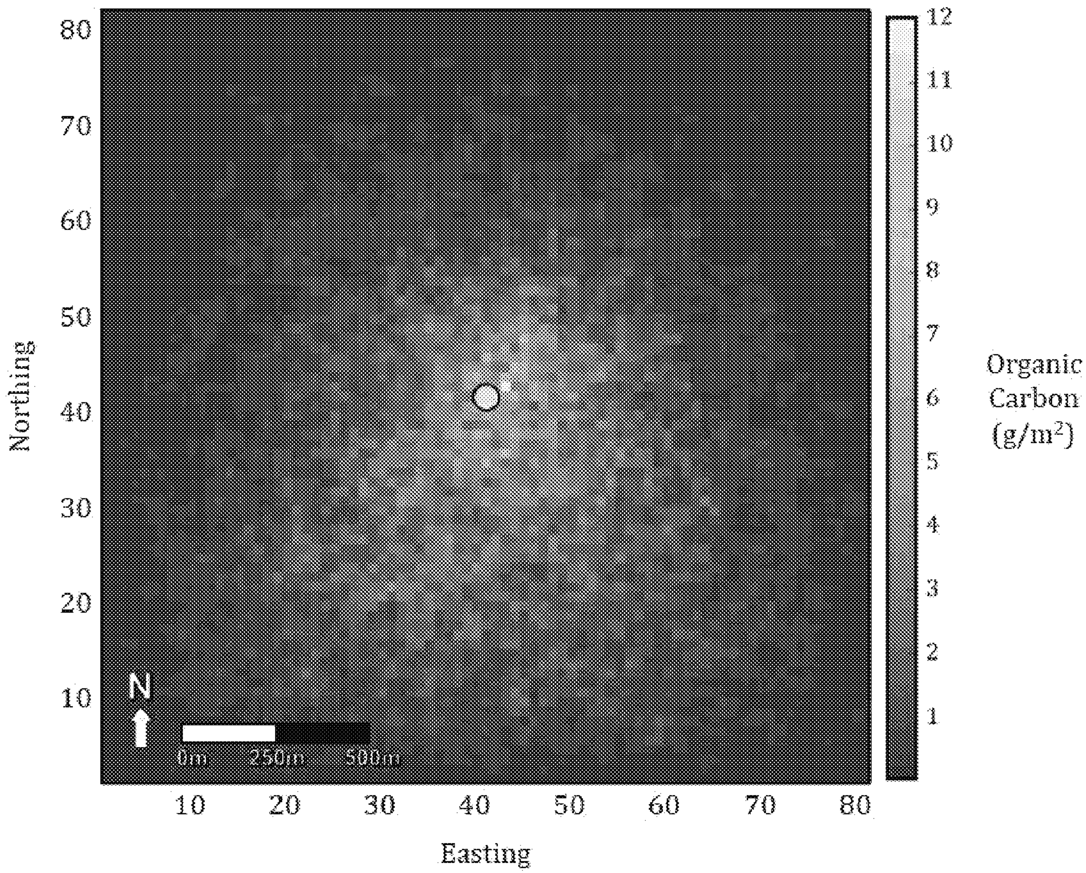

Figure 4. Predicted annual benthic carbon deposition field beneath two net pens with a standing stock biomass of 72,560 kg of Almaco Jack (*Seriola rivoliana*). Gray circle indicates center position of the net pen. Axes indicate simulation cell numbers and deposition mass is in grams. The center of the pens is located at (27.056275 N, -83.216743 W). Predicted carbon loading was derived from the 12-month time series relationship based on depositional flux with resuspension.

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